Piñon Pine IGCC Power Project

Project completed

Participant

Sierra Pacific Power Company

Additional Team Members

Foster Wheeler USA Corporation—architect, engineer, and constructor

The M.W. Kellogg Company—technology supplier

Bechtel Corporation—start-up engineer

Westinghouse Corporation—technology supplier

General Electric—technology supplier

Location

Reno, Storey County, NV (Sierra Pacific Power Company's Tracy Station)

Technology

Integrated gasification combined-cycle (IGCC) using the KRW air-blown pressurized fluidized-bed coal gasification system

Plant Capacity/Production

107 MWe (gross), 99 MWe (net)

Coal

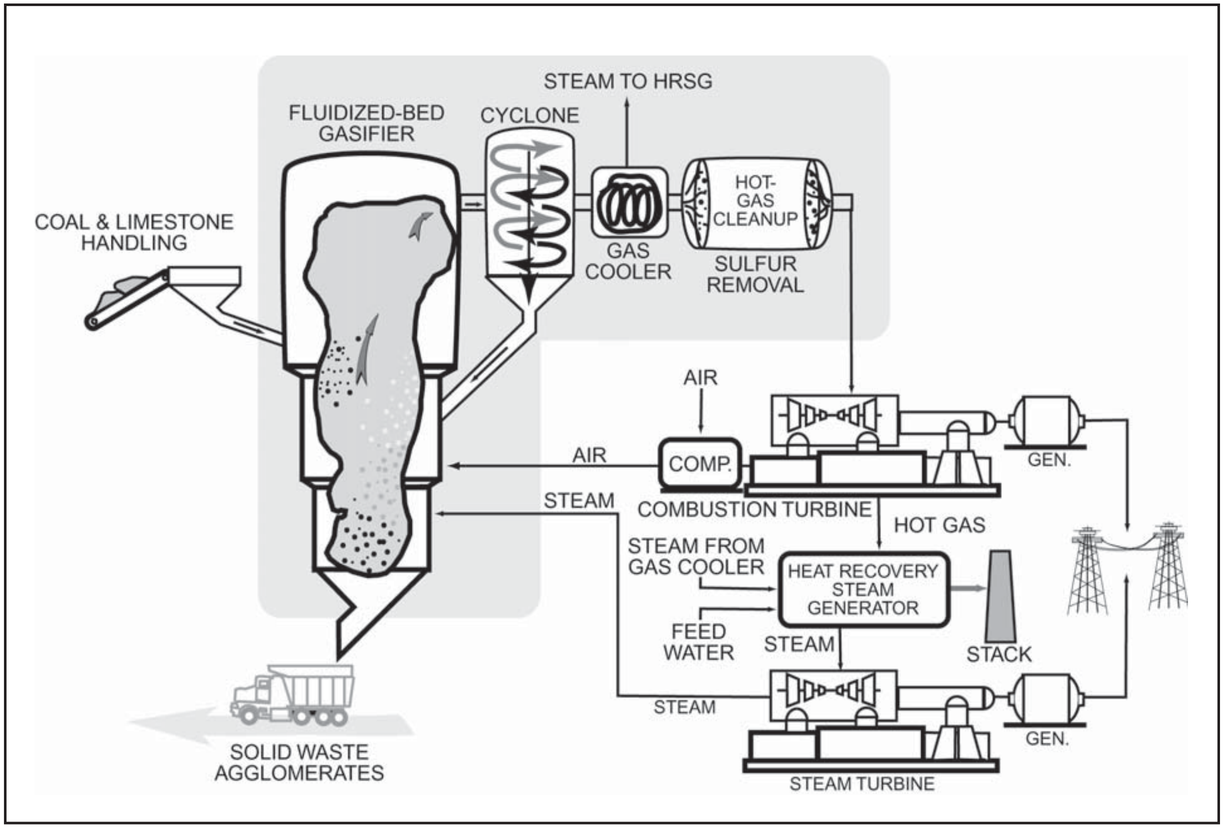
Southern Utah bituminous, 0.5–0.9% sulfur (design coal); Eastern bituminous, 2–3% sulfur (planned test)

Project Funding

Total	$335,913,000	100%
DOE	167,956,500	50
Participant	167,956,500	50

Project Objective

To demonstrate air-blown pressurized fluidized-bed IGCC technology incorporating hot gas cleanup (HGCU); to evaluate a low-Btu gas combustion turbine; and to assess long-term reliability, availability, maintainability, and environmental performance at a scale sufficient to determine commercial potential.



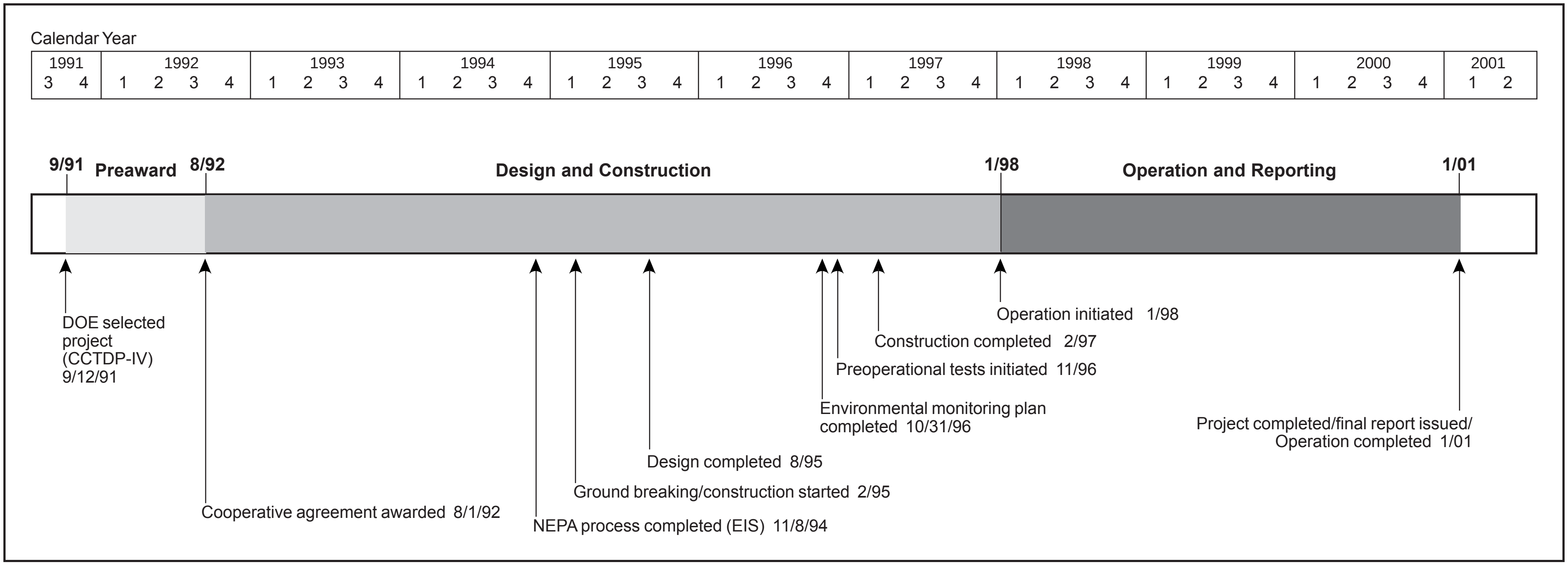
Technology/Project Description

Dried and crushed coal and limestone are introduced into a KRW air-blown pressurized fluidized-bed gasifier. Crushed limestone is used to capture a portion of the sulfur. The sulfur reacts with the limestone to form calcium sulfide which, after oxidation, exits as calcium sulfate along with the coal ash in the form of agglomerated particles suitable for landfill.

Low-Btu coal gas (140 Btu/standard cubic foot) leaving the gasifier passes through cyclones, which return most of the entrained particulate matter to the gasifier. The gas, which leaves the gasifier at about 1,700 ºF, is cooled to about 1,100 ºF before entering the hot gas cleanup system. During cleanup, virtually all of the remaining particulates are removed by ceramic candle filters, and final traces of sulfur are removed by reaction with a metal oxide sorbent in a transport reactor.

The cleaned gas then enters the GE MS6001FA (Frame 6FA) combustion turbine, which is coupled to a 61-MWe (gross) generator. Exhaust gas from the combustion turbine is used to produce steam in a heat recovery steam generator (HRSG). Superheated high-pressure steam drives a condensing steam turbine-generator designed to produce about 46 MWe (gross).

The IGCC plant is designed to remove more than 95% of the sulfur in the coal and emits 70% less NO_x and 20% less CO_2 than a comparable conventional coal-fired plant. The superior environmental performance is founded in the inherent efficiency of the pressurized fluidized-bed gasifier and incorporation of hot gas cleanup.



Results Summary

Operational

- The project succeeded in identifying and working through a number of problems, made possible only through full-scale system demonstrations, and positioned the technology for commercialization.
- Operational testing proved the ability of the KRW gasifier to produce coal-derived synthesis gas of design quality—two runs achieved 145 Btu/standard cubic foot.
- The power island demonstrated a 94% availability in a base load operating mode after working through a quality control problem in the HRSG, replacing an undersized turbine/generator coupling, and uncovering a shortcoming in the 2nd stage bucket shroud design in the hot gas path of the first-of-a-kind GE MS6001FA gas turbine.
- New start-up procedures for the IGCC system were developed to avoid accelerated temperature ramps upon ignition, which threatened the integrity of the refractory and ceramic candle filters, and to avoid use of an oxidant (air), which introduced the potential for fire. But, once up to temperature and operating, the gasifier proved to be easy to control.
- The fines removal system for the hot gas particulate filtration vessel was modified, which included increasing the size of the filter fines depressurization bin filters, using nuclear- and vibration-based level detectors in all the bins, and incorporating Skimmer valves (which provide bursts of high-pressure gas) to prevent bridging of fines in bin outlet sections.
- Testing suggested modifying the hot gas particulate filter to improve durability and enhance protection for the gas turbine in the event of candle element failures.
- The lower section of the gasifier was enlarged to facilitate limestone and ash (LASH) removal and cooling.
- The hot gas desulfurizer and regenerator system, using a transport reactor, showed promise after replacing the sorbent with a more physically durable material.

Environmental

- Steady-state operation was not reached in the course of testing, so environmental performance could not be evaluated.

Economic

- Steady-state operation was not reached in the course of testing, so economic performance could not be evaluated.

Project Summary

The project set out to assess pressurized fluidized-bed gasification technology, hot gas (1,000 °F) sulfur and particulate removal, and low-Btu gas combustion turbine performance in an IGCC application. The testing provided valuable information to guide developers in completing a course of action toward design of a commercial IGCC configuration embodying the basic system technologies. But the IGCC system did not reach steady-state operation, so environmental and economic performance could not be evaluated. Following is a synopsis of the results coming out of the operational assessment completed during the demonstration period.

Operational Performance

The power island, which includes the gas turbine, heat recovery steam generator (HRSG), and steam turbine began operation on natural gas in October 1996. The gas turbine is a General Electric MS6001FA—a first-of-a-kind unit designed to operate at a 2,350 °F firing temperature on 140 Btu/standard cubic foot coal-derived synthetic gas (syngas). Overall, the power island performance was good, demonstrating a 94% availability in a base load operating mode. Early operations uncovered some quality control problems in the HRSG and an undersized gas turbine/generator coupling, which were easily resolved. Also identified was a shortcoming in the 2nd stage bucket shroud design, which caused a premature failure. The shroud on the periphery of the 2nd stage bucket in the hot gas path distorted radially and contacted and damaged the honeycomb seal blocks. General Electric replaced the bucket assembly and returned the damaged parts for root cause analysis.

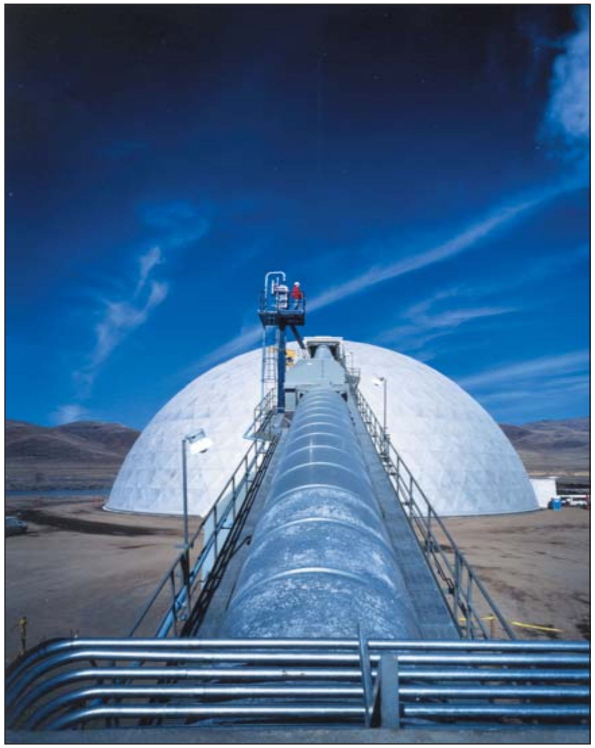
Testing of the gasifier island included 18 separate start-up attempts, each ending with a malfunction and incorporation of modifications to improve system performance. The longest syngas production run was 25 hours and the cumulative hours totaled 127.5. Although brief, the operation proved the ability of the KRW gasifier to produce coal-derived syngas of the quality predicted by design—two runs achieved 145 Btu/standard cubic foot. The unit experienced accelerated temperature ramps during start-up (once the bed is ignited), which induced spalling of the gasifier refractory and threatened the integrity of the ceramic candle filters in the hot gas particulate filtration system. Moreover, start-up used hot air, an oxidant, which has the potential to cause fires in a system normally operated in a reducing environment—residual fuel on or in components can catch fire if ignition temperatures are reached. A fire occurred during the last start-up and caused extensive damage to the hot gas particulate filtration system. At the close of the demonstration period, new inert gas start-up schemes were developed to address both rapid heat up and oxidation problems. Once up to temperature and operating, the gasifier proved easy to control.

Failure to remove fines from the hot gas particulate filtration (HGPF) vessel caused the bulk of failed start-ups. The system includes the HGPF, a screw feeder/cooler at the base of the HGPF, a filter fines collection bin (collection bin) to receive the HGPF fines, a filter fines depressurization bin (depressurization bin) to bring the system down to atmospheric pressure, and a filter fines feed bin (feed bin) to serve as a surge bin for the fines combustor. Testing led to development of several modifications to resolve the fines removal problems. Depressurization bin filters, through which vented gas passes to prevent emissions, were increased by an order of magnitude. Capacitance-type bin level detectors, including those in the HGPF, were replaced with nuclear level detection devices and vibration-based level detection, which subsequently functioned well. The HGPF vessel was further modified by incorporating a thermocouple array. Incorporation of Skimmer valves, providing a burst of high-pressure gas against the bin wall, in lieu of Evaser fluidizing nozzles, resolved the problem of fines bridging in the cone sections of the collection and depressurization bins.

Also, testing suggested modifying the hot gas particulate filter to improve durability and enhance protection for the gas turbine in the event of candle element failures. The ceramic candles are subject to failure from back-up of material in the fines removal system and thermal shock and fatigue failures. And, the safeguard devices (SGD), installed with each candle filter to plug upon candle failure, did not perform effectively. Moreover, candle breakage requires system shutdown because the broken pieces plug the fines removal system. Testing led to design of an alternative candle filter system that enhances durability and to SGD designs that show promise for major improvements.

Repeated start-ups, accelerated temperature ramps during start-up in early testing, and a two-layer refractory design resulted in spalling of the old refractory, which in turn plugged the LASH removal annulus. Moreover, the internal volume of the annulus proved to be too small to allow sufficient cooling of the LASH. Resolution included replacing the original two-layer refractory with new, single-layer refractory and fire brick in selected locations and increasing the annulus volume. The single castable layer of refractory, using a revised anchoring pattern, was installed from the grid area of the annulus up to 18 feet into the fluidized-bed region to provide the needed resistance to fatigue failure.


HRSG in foreground and gasifier island in background.



Conveyor leading to coal storage facility.

Failure of the fines removal system to provide a continuous output caused erratic operation of the fines combustor due to surging feed rates. The resultant surging of the combustor also contributed to seal damage between the combustor and HRSG. The solution was the addition of a diverter line from the fines removal system to the waste silo to provide an option prior to establishing a steady-state feed rate. An early candle filter failure pointed out poor SGD performance and inadequate protection for the recycle gas compressor, which experienced erosion of the impeller as a result of particulate incursion. The only other major failure was in the combustion air line, which burned through as a result of fuel accumulating in the line following system shutdown and bed slump. The solution was simply to blow out the line prior to start-up.

The hot gas desulfurizer and regeneration system showed promise. After the initial sorbent did not hold up physically in the entrained bed transport reactor system, another sorbent was identified and installed, and it performed well during the short runs.

The demonstration ended with Sierra Pacific trying to divest its power generation facilities, a condition of its earlier merger with Nevada Power. Wisconsin Public Service had expressed intentions to pursue commercialization of the Piñon Pine IGCC system and planned to purchase Sierra's Tracy Station, including the Piñon Pine Plant; however, the sale was cancelled by the Nevada legislature's imposition of a moratorium on sale of generation assets until July 2003. This reflects recognition that despite the difficulties encountered, the IGCC system shows promise. The demonstration resulted in the engineering knowledge requisite to establishing a commercial design for fluidized-bed gasification. The demonstration also provided valuable lessons learned for a broad range of advanced power generation technologies.

Commercial Applications

The Piñon Pine IGCC system concept is suitable for new power generation, repowering needs, and cogeneration applications. The net heat rate for a proposed greenfield plant using this technology is projected to be 7,800 Btu/kWh (43.7% efficiency), representing a 20% increase in thermal efficiency compared with a conventional pulverized coal plant with a scrubber and a comparable reduction in CO_2 emissions. The compactness of an IGCC system reduces space requirements per unit of energy generated relative to other coal-based power generation systems. The advantages provided by phased modular construction reduce the financial risk associated with new capacity additions. Furthermore, hot gas cleanup provides for extremely low emissions and efficiency gains through reduced heat loss.

The KRW IGCC technology offers tremendous fuel flexibility. It is capable of gasifying all types of coals, including high-sulfur, high-ash, low-rank, and high-swelling coals, as well as biowaste or refuse-derived waste, with minimal environmental impact. There are no significant process waste streams that require remediation. The only solid waste from the plant is a mixture of ash and calcium sulfate, a nonhazardous waste.

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